MODELS FOR THE PREDICTION OF HANDLING DAMAGE IN CITRUS AND PEACHES GRADING LINES, RELATED TO THEIR PHYSICAL PROPERTIES

Francisco García, Eng., Margarita Ruiz-Altisent, Prof.
Dept. Rural Eng. Polytechnic University Madrid
labpropfis2@iru.etsia.upm.es
Fernando Riquelme, Prof.
CEBAS Murcia, CSIC
friquelm@natura.cebas.csic.es

ABSTRACT
Fruit damage during harvesting and handling is a standing problem, particularly for susceptible fruits like peaches and apricots. The resulting mechanical damage is a combination of fruit properties and damage inflicting effects due to procedures and to the equipment. Nine packing lines in the region of Murcia (SE Spain) have been tested with the aid of two different-size electronic fruits IS-100. Probabilities of impacts above three preset thresholds (50 g's, 100 g's and 150 g's) were calculated for each transfer point. Interaction fruit-packing line tests have been also performed in order to study the real incidence of packing lines on natural produce: apricots (1 variety), peaches (3 v.), lemons (1 v.) and oranges (3 v.). Bruises of handled and not handled samples of fruits were compared.

INTRODUCTION
Under the frame of a R&D transfer Project, integrated by some leading co-operatives in the area of Murcia and two research institutes, Rural Engineering Dept. (Polytechnic University of Madrid) and Food Science and Technology Dept. (CEBAS-CSIC, Murcia), studies on damage susceptibility of stone and citrus fruits and harvesting and handling operations were carried out during two years. Results of the first of these studies are presented in a different paper by the same authors in this Symposium.
To get to know how a packing line affects to a fruit variety, information of two different nature must be available: about the packing line itself and data about the susceptibility of that variety. The information about the packing line is easier to get; normalized IS-100 tests are widely accepted and their results can be easily available and understood. On the other hand, many further approaches, under different points of view, have been carried out with the aim of finding the best way to predict and determine bruise thresholds and damage probabilities for apples (Bollen and Cox, 1994; Schulte and Pason, 1990). Few tests have been carried out for stone fruits (Kunze et al., 1975 ; Schulte et al., 1993 ; Barreiro, 1994); peach bruising has had less study than other species, i.e. apples, pears. Further testing is needed to establish similar thresholds (Brusewitz et al., 1991).
Although conclusions from different authors are not highly coincident, Table 1 and the following summarize some of them: Bruise susceptibility of peaches depends on the location of the inflicted impact (suture, shoulder, blossom end) (Brusewitz et al., 1991), firmness and ripeness state play also an important role on damage thresholds and bruise dimensions (Schulte et al., 1993;

Brusewitz et al., 1991), padding materials are only effective for firm fruits and for drop heights below 13 cm (Kunze et al., 1975 ; Shulte et al., 1993). In fruit to fruit impacts, damage thresholds lay in similar levels for both, falling and stationary fruits; padding materials in fruit-fruit impacts are not efficient for any of both fruits. Impact intensities of 50 g's, or higher, onto hard surfaces cause bruises of 0.5 cm^2, or higher. This bruise size supposes the highest allowable limit for exportable fruit. (Barreiro, 1994). Similar drop heights (3,5-7 cm) onto hard surfaces, cause different percentages of damaged fruits (Table 1).

Table 1. Percentage of damaged fruits in impacts onto hard surfaces.

Peach variety	Drop height (cm)	Damaged fruits (%)	Authors	Observations
Loring	3.5	100	Schulte et al., 1993	-
Red Haven	5.5	100	Schulte et al., 1993	-
Range/Red Skin	4.0	25	Kunze et al., 1975	-
Red Haven	5.0	40/80	Schulte et al., 1990	-
Range/Red Skin	7.0	30/23.3	Kunze et al., 1975	fruit-fruit impact

Researchers have generally described the bruise susceptibility of a produce in terms of its average bruise size (volume or area) as a function of energy. This method is not able to describe the variability of bruise occurrence in many fruit (Bollen and Cox, 1994). Although it is desirable to harvest fruits with a certain homogeneous ripeness stage, well trained pickers are not capable of picking peaches with precise maturity levels (Thai and Shewfelt, 1990). Concerning to citrus fruits, there have not been found previous results under a similar points of view. Citrus damage problems are more related to friction and abrasion effects than to impact or compression, although these have important effects on citrus damage as well, so taht the results will be presented in a similar format than stone fruit tests.

MATERIALS AND METHODS

Two instrumented spheres IS-100 were used to evaluate the quality of handling, grading and packing operations. Two different-size units were used: an orange-like one with 300.6 g weight and 8.8 cm diameter and a mandarin- or peach-like one weighing 114.7 g and with a diameter of 6.2 cm; both devices equipped with a triaxial accelerometer, a clock, a battery and a memory. Each impact data is reported as acceleration of gravity units (*g's*), where $1g = 9.8$ m/s^2 (Zapp et al., 1989). The impact duration, in *ms*, is also registered. Combining these two parameters it is possible to create other useful variables, like velocity change (Brown et al. 1990).

Nine packing lines belonging to six different cooperatives of the region of Murcia were tested, four for stone fruit and five for citrus (Garcia et al, 1996). Each grading line test was repeated 6 times at least.

Each packing line test was performed as follows: a.) Observation of the handling and packing line. Sketch drawing of the line. b.) Timing of the sphere crossing over the different elements along the grading line. c.) Data collection: Put the IS at the beginning of the line and let it run through it with other fruits. Note transfer times with an external clock. d.) Data analysis:

Identification of the high magnitude impacts, the element or transfer point where they take place and the kind of impacting surface.

The IS-100 results were managed in terms of probability of impacts with intensities above certain thresholds (50, 100 and 150 g's). The probabilities (P_i) were calculated as number of impacts above each preset threshold in each transfer (X g's) over the total number of runs in that transfer:

$$P_i = \frac{n \text{ of impacts} > X g's}{\text{total n of runs}}$$

In each packing line, the probability of inflicting, at least, one impact above 50, 100 and 150 g's was also calculated.

To investigate the incidence of packing lines on different products, a study on the interaction fruit-packing line was performed. The interaction between one stone fruit grading line and one apricot variety (*Búlida*) and three peach varieties (*Springcrest, Caterina,* and *Baby Gold*) was studied. Interactions between different citrus packing lines and one lemon variety (*Fino*) and three orange varieties (*Navelina, Salustiana Washington Navel*) were also performed.

Following UNE 34-117-81, ISO 874 Standards, two equal-size samples of recently harvested fruits were established, both belonging to the same shipment. The first sample was used as control. The second sample was established with fruit that had been subjected to the whole grading-handling-packing process. Every fruit of both samples was observed individually, paying attention to their mechanical damages. Surface and longitudinal damages were registered. The number and kind of damage of every fruit were noted.

For stone fruits, both samples were kept for 48 hours at room temperature (≈20 °C). Citrus were stored two weeks in cold storage (2 °C) and observed again. Damages were classified as shown in Table 2.

Table 2: Damage classes. Dimensions of bruises

Damage categories	Type of damage	
	Surface	Longitudinal
a	b.s. < 0.5 cm^2	l.d. < 1 cm
b	0.5 ≤ b.s. < 1 cm^2	1 ≤ l.d. < 2 cm
c	b.s. ≥ 1 cm^2	l.d. ≥ 2 cm

b.s.: bruise surface
l.d.: longitudinal damage

To simplify the abalysis of the information derived from this test, and only in the case of stone fruits, damage categories were redistributed, considering only two classes: exportable fruits (fruits with no damage or only 1 'a' damage) and non-exportable (fruits reporting more than one damage of any of the categories shown in Table 2). The results of these tests will be presented in these terms (Barreiro 1994). As citrus EU Quality Standards do not refer to quantitative bruise surface limits, but to qualitative, results are presented in terms of 'bruise size' -larger, smaller or equal to 50 mm^2-.

RESULTS AND DISCUSSION

Impact probabilities

Due to the large amount of information, only data of the large IS-100 (300.6 g weight, 8.8 cm diameter) will be presented.

Stone fruit packing lines (Fig. 1) show lower probabilities of impacts above 50 g's than citrus packing lines, although in almost all of them there exists, at least, one transfer point where the probability of impact above 50 g's is 100%. Only 'Valle-Abaran' co-operative, whose elements work at low speed, has no element with a 100% probability of impacts higher than 50 g's. 'Molinense 2' shows two transfers with very high probabilities (83.3 and 100%) of impacts above 100 g's.

Concerning the citrus packing lines (Fig. 2), the number of transfers with 100% probability of impacts above 50 g's varies between 5 and 8, considering that the total number of transfers in these lines is between 14 and 17. In both Figures 1 and 2, transfers whose impacting surface has been considered hard (steel or similar), are marked with an asterisk (*). Combining our criteria (impacts onto hard surfaces above 50 g's suppose, on stone fruits, bruise sizes ≥ 0.5 cm^2) with the data in Figure 1, we can conclude that almost 100% of fruits handled in these lines would result with damages above that bruise size. As said before, many other factors (firmness, ripeness stage, mechanical state of the product, etc.) affect undoubtedly these damage occurrence.

Citrus are specially susceptible to friction, but not so much to (pure) impact. As a fruits falls against a moving conveyor, friction is being inflicted on the contact area just at the moment of contact. Depending on the relative velocity of the fruit in relation to the velocity of the conveyor belt, the aggressiveness of the friction will vary. Bruise thresholds are not available for citrus, whereas situations as the explained above occur more than once in almost every citrus packing line of the ones tested.

Interaction packing line-fruit

Important differences in observed damages appear between not handled and handled samples: part of the damaged fruits belonging to the handled sample were manually removed during the handling process. Therefore, bruises found in fruits belonging to the handled sample are only a consequence of the mechanical process itself.

For stone fruit, more than 50 % of fruits of the handled sample showed some kind of damage. Non-exportable fruits vary from 37% -*Caterina* peaches- up to 61% -*Búlida* apricots-. After 48 hours storage, these percentages increased, reaching amounts of 53% and 76% of non-exportable fruits respectively.

Figure 3 shows that bruises do evolve after 48 hours storage at room temperature (≈20 °C) in every tested variety, increasing the percentage of non-exportable fruits, according to UE Standards.

A similar situation was found in citrus tests (Fig. 4): the percentage of fruits with bruise sizes larger than 50 mm^2 increases after 2 weeks at 2 °C, although not significatively. Handled fruits show more bruises of the mentioned dimensions than not handled fruits. All three tested orange varieties reach almost the maximum possible percentage of damaged fruits (Navelina: 100%, Salustiana: 97.5% and Washington Navel: 100%) with bruises larger than 50 mm^2 for the second observation. Even if this kind of damages may not affect the internal quality of the produce, they decrease its external appearance and subsequently its commercial value. Also, they are a way for the entry of diseases.

REFERENCES

Barreiro, P. 1994. Modelos para la simulación de daños mecánicos y desarrollo de un algoritmo de evaluación de maquinaria para los principales cultivares de albaricoque, manzana, melocotón y pera. PhD (Doctoral) Thesis. Polytechnic University Madrid.

Barreiro P., V. Steinmetz, M. Ruiz-Altisent. Neural bruise prediction models for fruit handling and machinery evaluation. Computers And Electronics In Agriculture, 1997. IFAC/CIGR/ EURAGENG /ISHS.

Bollen, A.F.; Cox, N.R.(1994) Probability of bruising - an alternative measure of bruise susceptibility.

Brown, G.K.; Schulte-Pason, N.L. 1990. Impact classification using an instrumented sphere. ASAE Meeting Presentation. Paper No. 90-6001.

Brusewitz, G.H. ; McCollum, T.G. ; Zhang, X. 1991. Impact bruise resistance of peaches. Transactions of the ASAE. pp. 962-965.

García, F., F. Riquelme , M. Ruiz-Altisent, P. Barreiro. 1996. Study of packing lines for stone fruits and citrus using two instrumented spheres in some cooperatives in the region of Murcia. Paper n° 96-F-038. AgEng '96 Conference on Agricultural Engineering. Madrid, 23-26 Sept. 1996 .

Kunze, O.R. ; Aldred, W.H. ; Reeder, B.D. 1975. Bruising characteristics of peaches related to mechanical harvesting. Transactions of the ASAE. pp. 939-941,945.

Miller, W.M.; Wagner, C. 1991. Florida citrus packimg line studies with an instrumented sphere. Applied Engineering in Agriculture. Vol. 7, Nr. 5, pp 577-581.

Miller, W.M.; Wagner, C. 1991. Impact studies in Florida citrus packinghouses using an instrumented sphere. Proc. Fla. State Hort. Soc. 104: 125-127.

Pang, W.; Studman, C.; Banks, N.H. 1991. Use of an instrumented sphere for assessing apple bruising thresholds. Inter. Winter Meeting of ASAE. Paper nr. 91 6596. Chicago, Illinois. December 1991.

Schulte-Pason, N.L.; Timm, E.J.; Brown, G.K.; Marshall, D.E.; Burton, C.L. 1990. Apple, peach and pear impact damage thresholds. ASAE Meeting Presentation. Paper No. 90-6002

Schulte-Pason, N.L.; Timm, E.J.; Brown, G.K. 1993. 'Red Haven' Peach Impact Damage Thresholds. ASAE Paper No. 935.18.

Thai and Shewfelt, 1990.Peach quality changes at different constant storage temperatures. Empyrical models. Trans. ASAE 33(1):227-233.

FIGURES 1-4

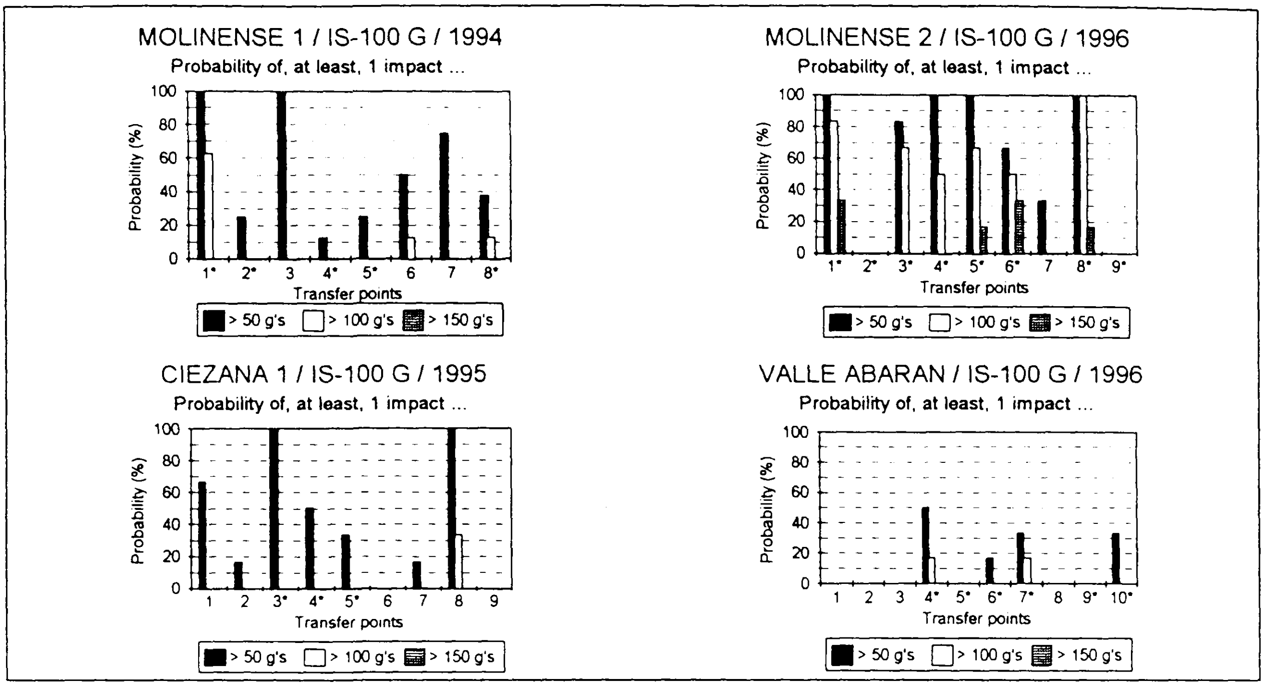

Figure 1. Probabilities of impacts above three different thresholds (50 g's, 100 g's and 150 g's) in every transfer of four stone fruit packing lines. Transfer points marked with an asterisk correspond to hard impacting surfaces (steel or other).

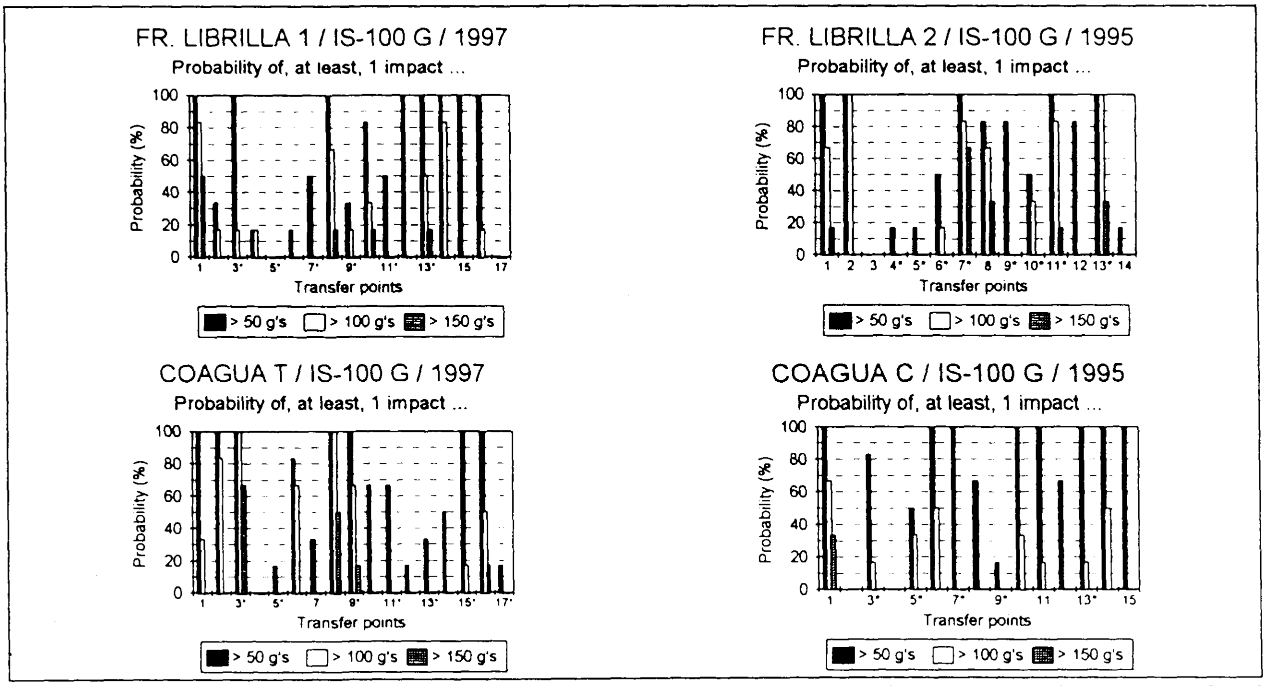

Figure 2. Probabilities of impacts above three different thresholds (50 g's, 100 g's and 150 g's) in every transfer of four citrus packing lines. Transfers marked with an asterisk correspond to hard impacting surfaces (steel or other).

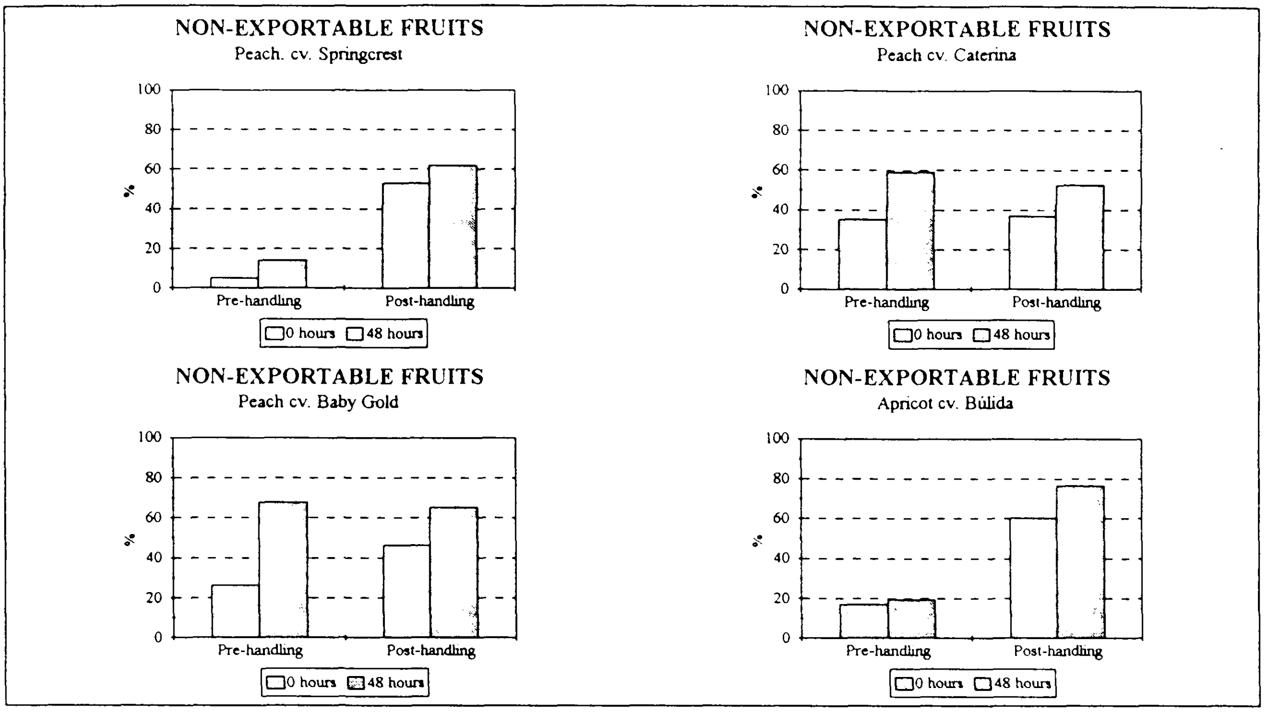

Figure 3. Percentages of 'non-exportable' fruits (≈ fruits out of Extra or Class I categories, according to UE Standards) before and after handling for stone fruit.

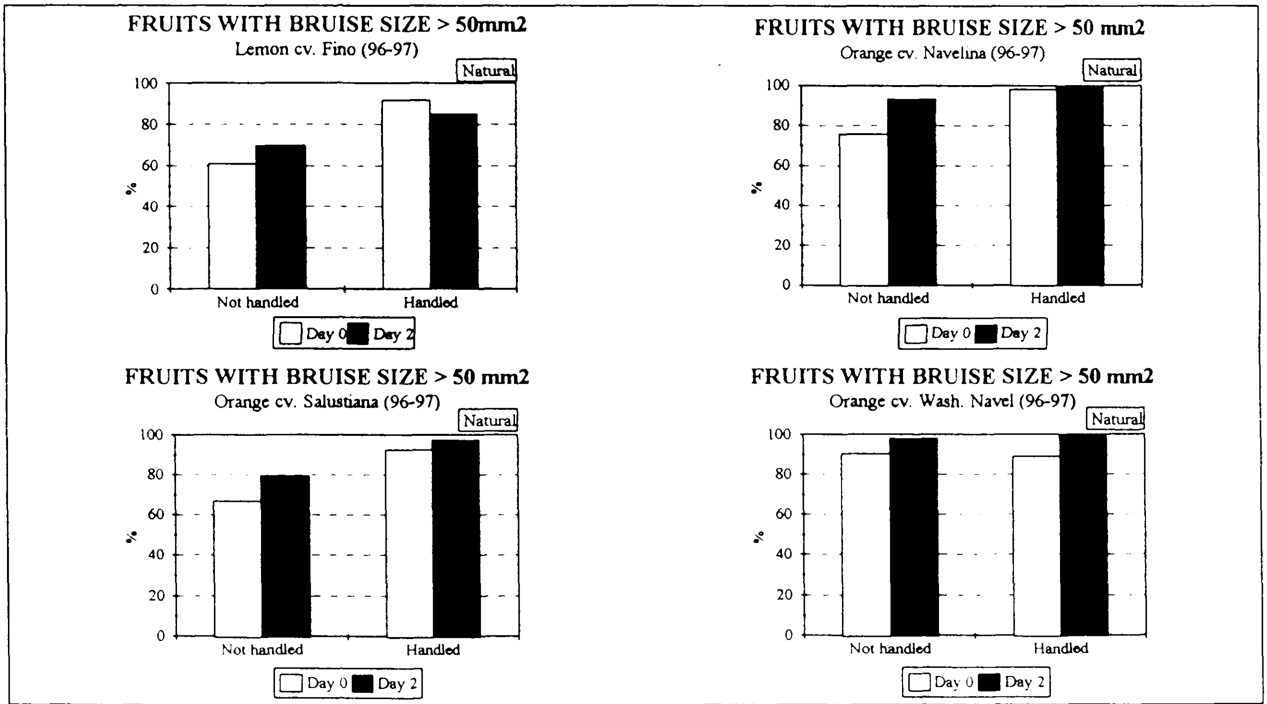

Figure 4. Percentages of fruits (citrus) with bruise sizes larger than 50 mm^2, for handled and not handled samples. Between the first damages observation and the second (after 7 days), they stored at 2 °C in cool chamber.